COMPARISON OF LONG-TERM CHANGES IN AIR AND SOIL TEMPERATURES AT URBANA, ILLINOIS

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ABSTRACT

Research concerning long-term temperature changes in the United States has shown the need to adjust measured increases in the 1901–1950 period to remove the effects of environmental changes. Unique long-term 3-ft. soil temperature data at Urbana, Ill., provide a measure of the natural increase in temperature in the 1903–1947 period and also permit an evaluation of the increase shown by the air temperature at Urbana. The increase in mean annual soil temperatures between 1903 and 1947 amounted to 1.2° F. The mean annual air temperatures during this period increased 2.3° F., but when adjusted statistically to remove environmental effects, the natural increase in the air temperature was 1.1° F. Thus, at Urbana, the adjusted increase in air temperatures appears to be substantiated by the increase shown by the 3-ft. soil temperature data.

1. INTRODUCTION

The primary purpose of this comparative study was to use soil temperature data to evaluate the measured and adjusted long-term increases in air temperature at Urbana, Ill. Because of various environmental changes, air temperature increases during the 1901–1950 period at Urbana and many other locations have to be statistically adjusted to obtain homogeneity or a true measure of the natural temperature increase. A method to accomplish this adjustment has been developed recently by Mitchell [5]. The increase in the 3-ft. soil temperatures, which can be considered to be largely unaffected by man-made influences and thus to reflect any natural change, was compared with the adjusted air temperature increase at Urbana where man-made and possibly instrument influences on the temperature were suspected.

At the weather station in Urbana air temperatures have been measured continuously since 1888 and soil temperatures at the 3-ft. depth were measured during 45 years in the 1889–1947 period. This station has been selected by the U.S. Weather Bureau as a national climatological "Benchmark" station. Because of minimal man-made influences and potential future permanency, these Benchmark stations should provide reliable past and future data on the natural climatic changes in air temperatures [4].

The major problem in determining the degree of natural temperature change in the United States is the lack of reliable long-term records. The temperature trends of most stations are not accurate measurements of true large-scale climatic changes because of environmental changes and movements of station locations. Mitchell [5] performed extensive statistical analyses of the temperature records from carefully selected stations located throughout the eastern United States. He wished to determine which stations had homogeneous records unaffected by man-made changes and by station relocations. Results of Mitchell's detailed statistical testing of 13 cooperative substations and 10 first-order stations in the eastern United States revealed that all these stations had either discontinuous inhomogeneities (major relocations) or progressive inhomogeneities (man-made influences). The Urbana station was among the 13 substations chosen for study, and the Urbana temperatures, like those of three other substations and the first-order stations, were found to contain progressive inhomogeneities. Between 1905 and 1954 this inhomogeneity at Urbana was +1.4 °F. on an annual basis. Thus, to obtain a measure of the natural increase in annual temperatures between 1905 and 1954, it is possible to achieve artificial homogeneity by subtracting the progressive inhomogeneity from the actual indicated increase. Obviously, an independent check of the validity of such a normalizing procedure is highly desirable.

The availability of the unique long-term soil temperature data for various depths at Urbana offered a potential means of measuring the natural temperature change during the 1889–1947 period, and also a means of evaluating the validity of adjusting the Urbana temperature records to artificial homogeneity. A careful search through the many old Urbana soil temperature records revealed that the most complete and longest available were those for the 3-ft. depth [1].

2. DATA

The 3-ft. soil temperatures were measured once daily with a standard glass thermometer suspended 3 ft. below the ground surface, inside a narrow glass tube which was sealed at the surface. Since this method of measurement

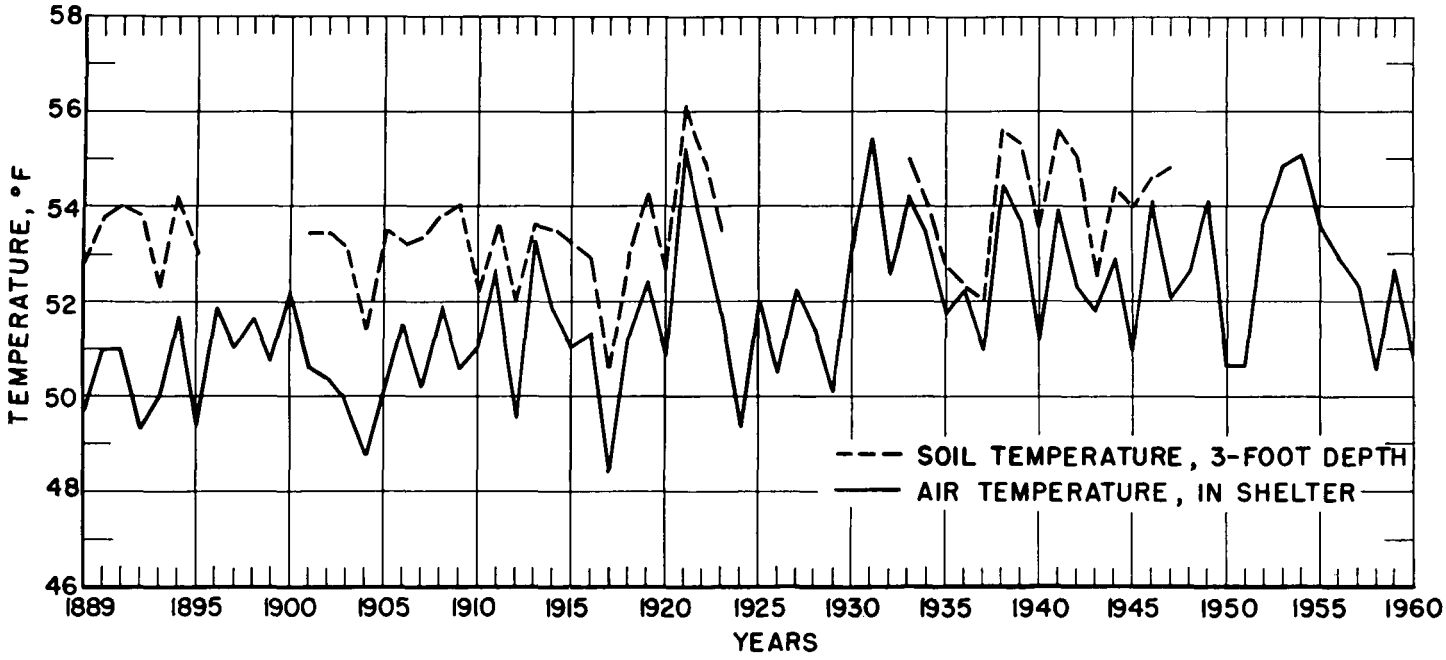

FIGURE 1.—Annual mean soil and air temperatures at Urbana, Ill.

was not altered throughout the 1889–1947 period, its absolute accuracy is not important to this study.

Annual temperature data at the 3-ft. depth were available for the 1889–1895 period, the 1901–1923 period, and for the 1933–1947 period. In each of these three periods the thermometer tube was located in slightly different locations, but all three locations had identical undisturbed soil types and similar types of grass cover. The soil at the 3-ft. depth is a natural subsoil of silty clay below a brown silt loam of prairie origin [2]. The air temperature data were measured using standard thermometers within a standard weather shelter located near the soil thermometer [1]. Although the soil temperature records were not continuous during the 1889–1947 period, they are sufficiently long to provide (1) a good measure of any long-term temperature changes at that depth, and (2) a basis for comparison with long-term changes in air temperature in the 1889–1947 period.

3. FINDINGS

Annual mean temperatures were used to compare the air and soil temperatures. The mean annual air temperature for the 1903–1912 decade was 50.6° F., and the mean for the decade ending in 1957 was 53.1° F. Thus, a 2.5° F. increase is indicated in the mean annual air temperature at Urbana. When the 1.4° F. inhomogeneity is subtracted, the true increase becomes 1.1° F. In an earlier analysis, Landsberg [3] indicated that increases of 1.0° to 1.5° F. would be representative of the annual temperature change in the 1906–1955 period in the Illinois area. Thus, Landsberg's preliminary findings agree generally with the adjusted temperature increase.

Figure 1 shows the annual mean air and soil temperatures. In each of the 45 years of annual data the 3-ft. soil temperature was higher than the air temperature. In general, the curves for the two temparatures have the same shape.

For further comparison, the data were divided into 5-yr. segments, and mean annual temperatures were computed for each of these pentads. These pentads and their mean annual air and soil temperatures are listed in table 1.

These data show the increase in annual temperatures. The mean annual air temperature for the 1903–1907 period was 50.1° F. compared with 52.4° F. in the 1943–1947 period. The mean annual 3-ft. soil temperature for

TABLE 1.—*Three-foot soil temperatures and air temperatures for 5-yr. periods*

5-yr. periods	Annual mean temperatures (° F.)		
	Air	Soil, 3-ft. depth	Difference, soil-air
1890–94	50.58	53.60	3.02
1903–07	50.10	52.90	2.80
1908–12	51.16	53.12	1.96
1913–17	51.16	52.76	1.60
1918–22	52.58	54.16	1.58
1933–37	52.50	53.20	.70
1938–42	53.10	54.98	1.88
1943–47	52.38	54.08	1.70

the 1903–1907 period was 52.9° F. compared with 54.1° F. in the 1943–1947 period. The progressive inhomogeneity through 1947 was approximately 1.2° F. for the annual air temperatures. The air temperature increase of 2.3° F. adjusted to homogeneity becomes 1.1° F., which closely matches the soil temperature increase of 1.2° F.

The difference between the mean annual air and soil temperatures for the pentads is also given in table 1. In the five earliest periods the differences ranged from 1.6° to 3.0° F., whereas in the three later periods the difference ranged from 0.7° to 1.9° F. If the inhomogeneity factor is subtracted from the air temperatures in the three later pentads, the differences range from 1.8° to 3.0° F., thus closely approximating the differences derived in the five earlier pentads.

4. CONCLUSIONS

Both the air and soil temperatures at Urbana during the 1903–1947 period revealed an increase with time reflecting the general temperature increase which occurred in the Northern Hemisphere during this period. The increase for the 3-ft. soil temperatures, which is assumed to be a natural increase, was 1.2° F., matching the increase obtained by adjusting the air temperatures. A 1.1° F. adjusted increase in the mean annual air temperatures occurred in the 1903–1947 period. The findings concerning the soil temperature increase substantiate the "natural" increase in air temperature calculated using a statistically determined homogeneity factor to adjust the air temperature data.

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